SMITH (H. L.)

Position in the Treatment of Elbow Joint Fractures.

AN EXPERIMENTAL STUDY.

BY

H. L. SMITH, M.D.,

ASSISTANT VISITING SURGEON, BOSTON CITY HOSPITAL.

Reprinted from the Boston Medical and Surgical Journal of October 18 and 25, 1894.

BOSTON:
DAMRELL & UPHAM, PUBLISHERS,
283 Washington Street.
1894.

S. J. PARKHILL & CO., PRINTERS
BOSTON

POSITION IN THE TREATMENT OF ELBOW-JOINT FRACTURES: AN EXPERIMENTAL STUDY.[1]

BY H. L. SMITH, M.D.

THE series of experiments here reported was undertaken with the view of determining, if possible, at what degree of flexion of the forearm, in the case of fractures involving the elbow-joint, the fragments were held in the best position. Such an investigation would seem to be desirable if only from the fact that there is a wide difference in the practice of competent surgeons. While it appears from Robert's paper read before the American Surgical Association two years ago, that the majority of practitioners dress these injuries with the arm at right angles, there is a considerable proportion (15 out of 88) who prefer to fix the forearm in the extended position. Of 65 who used the right-angled position, 37 did so because they thought it insured better coaptation of the fragments; while of the 15 who advocated the extended position 11 gave the self-same reason, namely, that the fragments were by that means more easily reduced and more accurately retained. Evidently both cannot be right.

So far as the writer is aware, no actual experiments have been made hitherto to determine the true facts in the case. It is not claimed, of course, that the conditions of a recent fracture can be exactly reproduced in the experimental work on the cadaver. The latter has been done on adult arms; the majority of the former are in children. One attempt was made to cause a fracture in the manner in which it usually occurs as an accident, but the thickness of the bones made it

[1] Read before the Surgical Section of the Suffolk District Medical Society, January 3, 1894.

well-nigh impossible, and the method to be described was used instead.

When the series was commenced the writer had no positive convictions as to the results he might expect to obtain; and, as a matter of fact, the conclusions reached, and the method of treatment which he has been led to adopt in all elbow-joint fractures were the outcome of these experiments solely.

The undesirable results in the case of elbow fractures are due usually to one of two things; (1) limitation of motion, (2) reversal of the normal humero-ulnar angle.

No doubt all would agree that the former of these factors is the one most to be avoided, but there are surgeons who consider the second alone of sufficient importance to be given as a reason for a special mode of treatment, namely, that by extension. Any method, therefore, devised for the treatment of these troublesome injuries, must be one which shall obviate, so far as that be possible, both these unwelcome results.

METHODS.

The first experiments were made upon undissected arms. The desired fracture was produced by driving an osteotome through the condyle with a mallet, a vertical incision, about a centimetre in length, having first been made just above one or the other epicondyle. After the chisel had been driven as far as was deemed necessary, the fragment was separated by prying. The fragment was then carefully examined as to its position, ease of displacement, best method of reposition, etc., in all positions of the forearm, from complete (forced) extension, to acute (forced) flexion. The same study was then made after the skin had been turned back, leaving the muscles exposed. Next the various muscular layers were removed in turn

until the behavior of the fragment when covered with the ligaments and capsule only could be studied. Finally the ligaments were cut, and the exact variety of fracture noted.

Later experiments were made with arms which had been partially dissected, and for the opportunity of using these, I am indebted to Professor Dwight of the Harvard Medical School. In these cases a method frequently employed has been the cutting of windows in front or behind the joint, and in this way it has been easy to study the behavior of the fragment with the least disturbance of its surroundings and attachments.

The experiments number in all twenty-four. Of the internal condyle there have been seven; of the external condyle, four; of transverse fractures across the lower end of the humerus, four; of "T" fractures, four; of the internal epicondyle, two; and of special fractures with certain additional injuries for the solution of special problems, three.

INTERNAL CONDYLE.

Experiment, August 14, 1892. Male adult. Left arm. Rigor mortis almost absent. Thoroughly broken down. Vertical incision, one centimetre long, just above internal epicondyle. A Macewen's osteotome introduced, and driven downward and inward, the condyle being broken off by prying with the osteotome.

With the arm extended there is increased lateral mobility of the forearm at the elbow, and crepitus can be felt when the fingers are upon the tip of the olecranon. By lateral pressure the humero-ulnar angle can be decreased and restored again. The external lateral ligament seems to prevent the forearm being brought farther than to a straight line with the humerus. With the forearm flexed to a right angle, the olecranon and fragment of the internal condyle can be displaced backward. With the arm extended this is not possible.

Skin reflected by an H-incision. When the arm is extended the muscles in front of the internal condyle are made tense over it and bulge forward, owing to the fact that the broken fragment tends to rotate forward, with its upper, broken surface looking forward and upward. It is held so rigidly in this position that it is difficult to replace it. When the arm is flexed to a right angle the tissues are loosely held, and replacement is easily made by pressure downward and backward upon the condyle. This can best be done by extending the arm and making as great a "carrying angle" as possible, and then flexing it steadily while the thumb of the other hand presses downward and backward upon the tip of the condyle, or upon the upper part of the shaft of the ulna. During this movement the forearm should be brought from a position of supination to one of semipronation. If then the same motion is continued to an acute angle, the internal condyle is kept firmly locked and held in its normal position. It cannot be dislodged from its position even by a very considerable force applied directly to it. If the fragments be fixed in this position by the fingers, and the forearm be extended without dislodging it, the humero-ulnar angle is found to be normal. In the extended position the fragment is invariably both rotated and bodily carried forward, and cannot be replaced until the forearm is flexed. The mobility of the fragment is greatest at the position of right angle, and then it steadily becomes less until an angle of a little more than 45° is obtained, at which point it is almost impossible to move it.[2]

The muscles are now stripped away in front of the joint, exposing the ligaments and capsule. In the extended position the fragment is in position only when the forearm is adducted in such a way as to decrease the humero-ulnar angle. If the forearm is carried outward so as to increase this angle, the broken surfaces are separated as much as a centimetre very easily. A very slight movement of the hand outward causes the tip of the olecranon to press the fragment out from its normal position,

[2] In this paper all angles are measured from the axis of the humerus, as a zero point, and not from the position of right angles.

leaving the above space between the broken surfaces. Close apposition is retained only by bringing the forearm inward as far as possible. If the fragment has already rotated forward in the manner described above, the arm being in the extended position, and if then the forearm is flexed to right angles without any special precautions, the fragment may retain its rotated position, the broken surface of the lower fragment still looking upward and forward. If, however, during the act of flexion, pressure is made downward and backward upon the internal condyle, or upon the ulna, this position is remedied. This manœuvre is best accomplished if the forearm is semi-pronated. The lateral ligament holds the fragment of internal condyle close to the ulna, from which it is never separated.

The capsule is now cleaned off thoroughly. It is very easy to displace the whole fragment forward. This is done by pressure upon the olecranon when the arm is extended, or by supinating the hand forcibly, thus twisting the ulna around the radius. When the hand is semi-pronated this is avoided. When the forearm is forcibly adducted so as to destroy the normal humero-ulnar angle, the fragment is displaced forward as well as upward, a very slight amount of motion of the fragment in this direction making a considerable deviation in the direction of the forearm. Simply putting the arm in the extended position, without carefully pressing the ulna backward at its upper end is not sufficient to reduce the fragment. The latter is more apt to be displaced than in the right-angled position, for the olecranon is naturally pushed forward, and there is no leverage for preventing it.

After repeated observations the following conclusion was found to be true: by bringing the forearm into the acute position, with the downward and backward pressure in front of the internal condyle, and with the forearm semi-pronated, the deformity is always reduced, and the fragment is firmly locked in position.

The line of fracture is found to terminate below at the dividing line, between the trochlea and the capitellum.

The result obtained in this experiment was entirely

unexpected, and the exactness with which the broken fragment was brought into its true position, and the absolute firmness with which it was held there was very surprising. The ground was gone over again and again, and in every instance with the same result. Just what tissues acted as the controlling force in this locking of the fragments could not be determined from this experiment alone. That point will be discussed later.

Experiment, September 24, 1892. Male, of large bone and muscular. Vertical incision above internal condyle; chisel introduced, and a fracture produced, with a distinct crack.

With abduction of the extended forearm, combined with a slight amount of flexion, the olecranon is thrown out of its fossa, causing it to protrude on the inner aspect of the arm beyond the internal condyle. This dislocation is very easily produced. With the arm forcibly extended the internal condyle is firmly fixed, apparently by the muscles passing in front of it. With the finger in the wound, which is made just large enough to admit the tip of one finger, the fragment is felt to be displaced forward and also, apparently, rotated on its lateral axis, so that it projects about a centimetre beyond the broken surface of the humerus above. The external lateral ligament is felt to be fairly tense. With adduction carried as far as possible, so that arm and forearm appear to be in the same straight line, there is a slight separation (half a centimetre), between the fragments at the innermost edge. If the forearm is abducted so that it reaches an angle corresponding to the sound arm, the fragments are separated so as to admit the tip of the finger, or at least a centimetre. If an attempt is made to replace the fragment in position, while the forearm is somewhat flexed, and extension is again made, the displacement invariably recurs with the same results as before.

With the forearm slightly flexed (160°), the forward rotation can be corrected by pressure on the upper edge of the fragment with the finger in the wound, but it is done with

great difficulty or not at all when attempted from outside the skin, and in any case returns at once when pressure is omitted. Displacement forward is more marked than before, and can best be reduced by semi-pronation of the forearm. Complete supination is certain to cause this

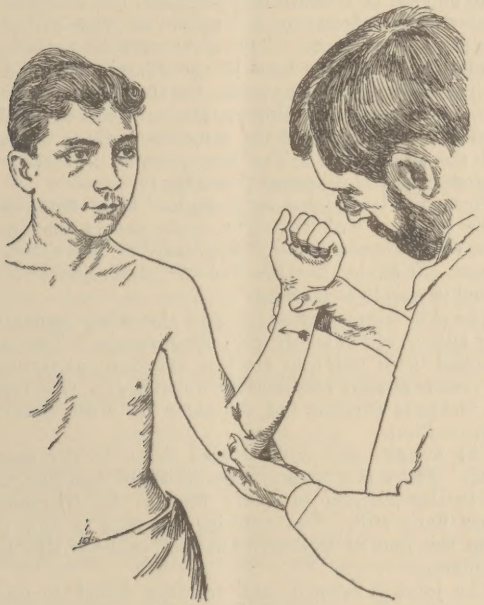

FIG. 1.

separation to the extent of one centimetre. If the forearm is strongly adducted, making the whole arm straight, the fragments are held together, but the forward displacement is not corrected. With the forearm carried outward to its normal angle, the whole index-finger can be placed between the fragments. Slightly forced supination makes the anterior displacement very much greater.

Further flexion of the forearm increases the mobility of the fragment, until the right angle is reached, when it suddenly, from a condition of free mobility in all directions, becomes quite firmly fixed, allowing only a slight forward and backward rotation on its lateral axis. There is a slight amount of forward displacement, but it can be easily reduced by the finger in the wound or from without, and does not tend to recur. The manœuvre of replacing it is as follows: Grasp the back of the elbow with the palm of the left (with left elbow) hand, the thumb reaching around in front of the ulna. Make pressure downward and backward with the thumb, at the same time flexing the forearm with the other hand. The best position is obtained with the forearm semi-pronated (see Fig. 1).

Flexion to less than a right angle. If at 60°, the result is the same as with the right angle, except that the fragment is held more firmly, apparently by the action of the triceps. If flexion is carried to 45°, the fragment is firmly locked in excellent position.

The skin is now reflected, and the whole ground gone over again, with exactly the same results. The muscles attached to the external condyle are now cut through, but the results already obtained are unchanged. The tendon of the biceps is divided, but the same facts are observed in each position.

The muscles are now divided down to the capsule in front. There is a greater possibility of anterior rotation, but in the position of acute flexion the fragments are firmly fixed still. The anterior ligament is now divided along the line of fracture, but the position still remains excellent.

The joint is opened, and fracture found to terminate below at the groove inside the capitellum.

In this case the fact was brought out very clearly that it was extremely difficult to bring the fragments into position while the forearm was extended.

Experiment, Harvard Medical School, November 3, 1893. Muscular man. Left arm. All muscles in position. With chisel the internal condyle is broken off obliquely

into the joint. The line of fracture is found later to run to the middle of the trochlear surface below. In extension the fragment is movable in every direction. In the right-angled position the same is true. In acute flexion it is held firmly in place.

The lateral and anterior ligaments are cut, without affecting these results. The external condyle is now fractured in the same arm. It is also freely movable except in acute flexion. The triceps is now cut through, leaving the posterior ligament, and the results remain unchanged.

Elbow is now stripped of everything except the posterior ligament. In the extended position the fragments are widely separated from position, and dangle loosely, but when the manœuvre already described is gone through with, the parts come into place perfectly.

In four other cases of fracture of the internal condyle a similar study was made, with slightly varied conditions, such as making windows in front of the joint, cutting different ligaments, muscular structures, etc., but the results were so uniformly in accord with those of the preceding experiments that they will not be given in detail.

EXTERNAL CONDYLE.

Experiment, August 25, 1892. Adult. Left elbow. Rigor mortis present. Broken down. Vertical incision, one centimetre long, with its lower border one centimetre above external condyle. Osteotome introduced, turned to right angle, and condyle chipped off apparently into the joint.

Condyle movable, though not easily. Crepitus most easily obtained by going through the motions of extending and flexing the forearm. Line of fracture can be distinctly felt through the skin. Least mobility when forearm is acutely flexed, greatest when the arm is half-way between full extension and a right angle. No abnormality of relation between bony outlines discovered by feeling.

H-incision and flaps of skin turned down and up. In the right-angled position backward pressure on upper end

of radius easily causes separation of the fractured surfaces. With the arm in position of acute flexion, interval is not so great.

Muscle divided down to capsule, and reflected. With abduction and adduction of forearm (side to side), the broken fragment closely follows the head of the radius. Broken surfaces easily separated half a centimetre, on firm adduction, with arm extended. With arm at right angles, hand supinated, a slight amount of pressure downward on head of radius separates the fragment, so that the little finger can be introduced between the bones. With the same pressure, if the hand is pronated, this separation is not produced. If pressure is omitted, the forearm being pronated, the fragments approximate each other. With the arm acutely flexed (45°), the fragments remain in good position. Downward pressure on the head of the radius then causes only slight separation.

At this point the osteotome was re-introduced and the fragment more thoroughly freed from the rest of the humerus at its inner end, where it seemed to be slightly adherent. In the extended position the fragment is in fair place, with separation of one centimetre. At the right-angle position the separation is wide and can be decreased only by upward pressure on the radius. In the acute position the fragment is brought into position automatically, and cannot be displaced. No anterior displacement in full extension. With the arm fully extended, and abduction and adduction performed, there is a motion of about half a centimetre between fragments. At right angles, with upward and downward pressure on the radius, two centimetres is possible; in the acute position almost nothing. In flexion of two to three degrees from full extension, that is, as soon as the olecranon is slightly freed from the fossa, the displacement is as great as at right angles.

Capsule cut anteriorly, leaving those fibres connecting the fragment and the radial head. The line of fracture runs across anterior surface of capitellum, its lowest point reaching a little beyond the centre of the trochlear surface.

Experiment. Right arm. Rigor mortis. Broken down. Same incision as before. Intention is to break off less of

condyle. Fragment distinctly movable, particularly when arm is half-way between extension and a right angle. In acute flexion it is firm, as before.

Skin reflected, arm extended fully. It is found that the fragment is carried forward so that the broken surface of the lower fragment projects in front of the upper. At right angles there is good position, the fragments being separated only slightly by downward pressure on the radius.

Muscles cut through above the joint and reflected downward, exposing the capsule. In the extended position the fragment is rotated outward and very slightly forward (can be moved one-half to one centimetre). With arm slightly flexed, so that the olecranon is free, the fragment is rotated still further outward, but can be approximated by forcible abduction, and separated one to two centimetres by adduction. At right angles, the movement is two centimetres, by upward and downward pressure on radius. Much better position when the arm is semi-prone than when supine, if same amount of downward pressure is used. With hand semi-prone and no downward pressure, the fragments are in good position and held firmly.

Arm acutely flexed. Fragments almost perfectly immovable, in good position. When arm is in any position but complete extension and full acute flexion, it is perfectly possible to dislocate the fragment forward.

The surest manœuvre for replacing the fragment is longitudinal extension, with forearm extended, followed by flexion, the thumb at the same time making downward and backward pressure on the upper end of the ulna, the motion being carried to acute flexion.

Capsule opened, leaving fragment attached to the radius. Line of fracture found to penetrate the joint at the capitellum, its lowest point appearing at the line of junction (externally) of the capitellum and trochlear surface. Joint forcibly dislocated by abduction and backward pressure. It results in displacement of the fragment so that the external condyle lies with its broken surface looking forward and lying in a plane posterior to the plane of the normal condyles. By flexing to right angles the fragment is brought nearly to position (half a centimetre) without other manipulation. If this motion is carried to

an acute angle, the bones accurately approximate and are firmly locked. This movement is repeated several times with the same result.

From the foregoing experiments and from two others not detailed here, it would appear that acute flexion at the elbow serves to replace and retain the broken-off fragment of the external condyle as well as it did that of the internal condyle. In every case the fragment was firmly attached to the head of the radius, which it followed in all its movements, so that it became very easy, when the head of the radius was somewhat loosened, to displace the fragment forward in such a way as to prevent flexion of the forearm beyond the right angle. The writer has met with this condition quite frequently in practice, and in such cases he has found that the use of the acute position becomes almost a necessity if the power of full flexion is to be retained, irrespective of the power of this position to hold the fractured condyle in place. It is in precisely this variety of fracture, namely, that of the external condyle, that treatment by acute flexion has been employed at various times in the past; and it is interesting to observe how fully this mode of treatment is justified by a theoretical study of the conditions present in such an injury.

TRANSVERSE FRACTURES.

Four fractures of this sort were made, the line of fracture usually running transversely just above the torchlea and capitellum. In one case the line was lower, passing through the capitellum, and this simulated more nearly the condition of the epipheseal separation. It is now the conviction of the writer, although he has not concluded his study of the subject, that the cases of "gun-stock deformity" occur usually

after fractures which run completely across the bone, including in this list T-fractures and separations of the epiphysis, and that it does not occur as a rule after fractures of a single condyle. Such transverse or complicated fractures allow of considerable rotation of the fragment upon the long axis of the humerus. If this be the case, and then complete extension of the forearm is not recovered (the loss of the last few degrees of extension being very common, as the result of the filling of the olecranon fossa, or of adhesions, and usually being of little or no consequence so far as the functions of the organ are concerned), there results a deformity closely resembling a true reversed humero-ulnar angle. Even where the deformity is due to the changing of the axis of the torchlea, the previous injury has been usually other than the fracture of a condyle in the cases (upward of one hundred) examined by the writer.

From purely theoretical considerations it might be doubted whether a distinct transverse fracture would be retained in good position by acute flexion — whether the lower fragment would not be tilted forward upon its lateral axis. This seems, however, not to happen, or at any rate to such a slight extent as to be safely disregarded in view of the firmness with which the parts are bound together. The following is a type of the results obtained in this variety of fracture.

Experiment, November 6, 1893. Right arm. Muscle in place. Biceps only have been removed. A window is cut in front of the joint. Then with the chisel the lower end of the humerus is cut through just above the condyles. In the extended position the surfaces are separated for at least a centimetre, and are very movable. In the right-angled position the parts are brought pretty well into place, but can be displaced without much trouble. By rotating the forearm inward, as if it were placed across the chest, the

lower fragment can be turned around upon its axis for twenty degrees (estimated), and then if it remains there the carrying angle is apt to be decreased almost to nothing, although it was not observed to become an inward angle. In the case of acute flexion the broken surfaces are brought into exact contact and held in place very firmly. In this position carrying the arm inward does not cause the same rotation of the fragment, because, apparently, it is locked in place.

T-FRACTURES.

Experiment, August 27, 1892. Adult female. Left arm. Rigor mortis very slight. Vertical incision, two centimetres above the internal condyle. A small bone drill passed partially through the condyle towards the joint. It stuck in the bone, and was withdrawn. The condyle was then partially chiselled through in the same direction. The elbow was then raised upon the edge of the table, with the forearm vertical, and repeated blows were made with a wooden mallet, the hand being extended, so that the blows might be made upon the palm in the direction of the forearm axis. A slight crack was heard, but nothing definite was accomplished in this way. The forearm was then forcibly abducted over the edge of the table. Apparently the fibres of the posterior ligament attached to the olecranon were broken through. Attempts were now made to break the internal condyle by strong adduction, but they were not successful. It had been thought that a fracture brought about by direct or indirect force might present conditions nearer those found in the case of fresh breaks during life, but as it was so difficult to produce the fracture in the adult arm the chisel was resorted to again, and all the fractures of this series of experiments were produced in that way.

After being chiselled off, the internal condyle felt freely movable backward and forward, and seemed to be held firmly to the ulna. The olecranon could be partially displaced inward by flexion and abduction of the forearm.

In the extended position the fragment is pretty firmly locked, and seems to be in fairly good position. The "carrying angle" is normal, and the forearm cannot be

brought into a straight line with the arm. A forcible attempt is made to bring the internal condyle far enough upward to make the angle an internal one, so as to produce the "gun-stock" deformity. This is accomplished by strongly adducting the forearm. As this act is performed, something is heard to break with a loud snap. The lateral mobility of the joint is now very free, and the elbow angle can be made a slightly internal one. The internal condyle still follows the ulna. When the joint is opened later, it is found that the first break went through the middle of the trochlea. The second line of fracture began in the centre of the first, ran across the bone at its thinnest part, and passed through the middle of the external condyle. It was observed that the outer fragment followed the head of the radius closely.

The bones of the forearm, with the fragments, can be displaced backward upon the shaft of the humerus. By reducing the dislocation, and then putting the forearm in the extended position, the second, transverse, fracture seems to be brought into good position. The internal condyle is in fair position, but is quite movable, and seems to project slightly forward. The forearm can be easily hyperextended. With a few degrees of flexion (140°) the fragments are all very loose, and could not be held in position easily, it would appear, by a simple anterior splint. The muscular masses which seemed before to aid in holding the parts firmly are now quite loose.

In the position of right angles, with the hand supine, if downward pressure is made upon the upper part of the forearm, the second fracture is held in good position, but can be easily moved. In this position it is easy to get the backward displacement at the elbow, unless constant pressure and counter-pressure are made upon the broken portion — backward upon the shaft of the humerus, and forward by pulling the forearm. Upward pressure upon the upper end of the ulna, with the arm at right angles, forces the inner side of the arm, together with the internal condyle, upward. The ulna and radius are then brought into nearly the same horizontal plane. This appears to be done by the rotation of the lower fragment of the humerus, as a whole, upon the antero-posterior axis. With the hand in the semi-

prone position the two bones can be kept parallel, in their natural planes, and in their proper positions. In this case the fragments remain as before, being unaffected by the change in the position of the forearm.

If the dislocation is reduced, and then the forearm brought into the position of acute flexion, the fragments are kept in good position, and held more firmly than in any other position of the forearm; but if care is not taken, there is a tendency for the lower fragment of the humerus to rotate forward on its lateral axis. This tendency, however, is but slight.

The skin and fat are now removed, exposing the muscles. In the extended position, when the humero-ulnar angle is made as large as that of the sound arm, there is a separation of at least one centimetre between the upper edges of the line of fracture, due to the fact that the fragment is rotated outward, and prevented from coming into place by the structures which bind it to the ulna on the side. In order to bring the broken surfaces into position, the forearm must be adducted until it is in a straight line with the upper arm.

In the right-angled position, with the hand supine, pressure upward upon the ulna brings the surfaces in contact, since the structures which bind the internal condyle to the ulna are now relaxed, and offer no resistance. Apparently it is the muscular masses, acting through the dense fibrous band to which they are attached, which form the main factor in this steadying of the fragment. If the hand is semi-pronated and at the same time downward pressure is made upon the ulna, the fragments are kept in normal position, and the "carrying angle" is preserved, as is shown by holding the fragment fixed with one hand while the forearm is slowly extended. With the hand semi-prone, the bones can best be brought into the same plane, and therefore the danger of raising the ulna to the plane of the radius is not so great.

In the acute position the same conclusions are reached as before the removal of the skin. By constant downward pressure upon the ulna, the internal fragment is kept in position, and the normal angle between humerus and ulna is found to be preserved.

A small knife is now introduced vertically into the muscular mass over the internal condyle, and all the ligaments uniting the condyle with the ulna divided as far as possible, leaving the muscular bellies and the fibrous septa as nearly intact as possible. The fragment is still found to follow all the movements of the ulna, because the intermuscular septum is attached to the ulna, and the only way to free the fragment would be to rupture this entirely through.

In the extended position the outward rolling is still more marked, and the separation greater than it was before. The fragment is now very loose, but it can be almost exactly replaced by bringing the arm into the position of acute flexion, forcing the ulna downward at the same time, and pressing the condyle firmly downward and backward.

The muscles are divided down to the capsule. In the extended position it is almost impossible to get the fragment in place by manipulation with the fingers; it persists in rolling outward. In the acute position the replacement can be done very easily and well. To accomplish it best, downward pressure should be made upon the forearm while the movement of flexion is being performed.

Undoubtedly the most unfortunate results after elbow-joint fractures occur from T-fractures, or those of greater comminution; and these cases have been studied with the greatest care, in order to be perfectly sure that the conclusions drawn are warranted by the facts. The foregoing is a typical fracture of this sort, the results obtained in the other experiments being identical. If it were possible to treat the living arm in a position of forced extension, the fragments might be held fairly well in position by the muscular bellies passing over them in front. But this is clearly impossible. The advocates of the extended position in the treatment of these injuries are careful to place the forearm at a point slightly less than full extension, and it is in exactly this position that the fragments were found to be most loosely held.

It is here, too, that the value of semi-pronation of

the forearm is seen, since it was found in some of the experiments that the mere act of supination would carry the outer fragment distinctly away from its place, and the pressure such as is caused by the ordinary form of anterior angular splint would make this separation very considerable.

INTERNAL EPICONDYLE.

These fractures are of small consequence, and result favorably no matter what the position chosen. In no case were they produced purposely, but in two cases where the fractures resulted accidentally when it was intended to chip off more of the condyle, it was found that the fixation was more complete with the arm flexed to less than a right angle.

SPECIAL PROBLEMS.

Experiment, November 7, 1893. A variety of "T"-fracture. To show whether, if the posterior ligament is divided, the tendon of the triceps alone is sufficient to bind the fragments in place.

Large left arm. Chiselled over internal epicondyle. The epicondyle alone is at first broken off, and then by continuing the chiselling the joint is apparently opened. This is afterward found to be true, the line of fracture running nearly to the centre of the trochlea below. Then the external condyle is chiselled into the joint. The line of this fracture is afterward found to enter the first one at about the centre of the trochlea in front. It is therefore a kind of T-fracture.

In complete flexion the fragments are now held in place pretty firmly, although the internal epicondyle can be moved slightly. In all other positions the fragments can be easily moved with the movements of the forearm.

A knife blade is introduced above and behind the external condyle, and all the ligamentous fibres behind and over it are cut through, leaving only the tendon of the triceps. The fibres of the anconeus are all cut through.

The results do not differ from those obtained before, the fragments being held in position just as well.

A window is cut through in front in order to see where the line of fracture runs. The same movements are again gone through with, with exactly the same results. Complete extension is now seen to separate the fragments in front a distance of at least half a centimetre. The locking force seems to be the coronoid process in front and the tendon of the triceps behind.

Experiment. To see if a fractured olecranon would allow of lateral mobility of the forearm, so as to modify the "carrying angle."

Large arm. Ligaments dry and stiff. Olecranon chiselled through at about the junction of the epiphysis. The aponeurosis covering the posterior surface is not entirely broken through, so that the fractured extremity does not separate from the body of the bone on flexing forearm. There is considerable lateral mobility of the fragment, and crepitus easily obtained. No amount of lateral prying of the forearm will cause any appreciable difference in the angle. To make a difference in the angle, one of the lateral ligaments would have to be broken.

This study has slight bearing on the points at issue in this paper, and is inserted because of its importance in a complete study of the value of the "carrying angle" and the cause and importance of its loss.

Experiment, November 13, 1893. Medical School. To discover whether, with posterior and lateral ligaments divided, the triceps tendon remaining, the extended position is best.

Arm with muscles remaining. Chisel introduced above internal epicondyle, and the lower end of the humerus cut across. The line of fracture runs a little downward, but apparently passes above the capitellum. Without cutting the ligaments the forearm is first placed in various degrees of flexion. In the extended position the upper end of the lower fragment rides forward and presses firmly against the muscles in front of the joint. The fragment can be moved somewhat, although it is partially held, of course,

by the dense tissues in front. In the right-angled position the fragment is quite loose, and can be moved in all directions pretty freely. In this position it is very easy to turn the fragment upon its long axis (the axis of the humerus), and apparently this would be done by bringing the arm across the chest, with the forearm in a sling, in the usual way. When the fragment is rotated in this way and then the forearm extended, it is evident that the "carrying angle" is decreased, but it is not made an internal angle. In this position if upward pressure is made beneath the upper end of the ulna, there is a tendency for the fragment to be bent one way or another at the point of fracture, the direction of the bending depending upon the direction of the force. If extension in the line of the humerus could be kept up in this position, the fragment would be kept pretty well in place.

In the acute position the fragment is held firmly in place at its upper end, although there is a tendency for its direction to be changed so that it points forward more than the shaft of the bone above. This change in direction is not very great, and even if union were to take place in that position the deformity would not be noticeable. This forward tilting can be almost entirely corrected by going through the manœuvre already described, and making strong downward traction. Rotation of the fragment in the axis of the humerus now takes place only if considerable force is used, since the rough edges of the broken surfaces become interlocked.

A T-fracture is now made of this specimen, and then the same test is repeated, with the same result, although the two fractured condyles are not held quite so tightly as was the single piece.

In this case the same study was made before the posterior ligament was cut and afterward, and the results were essentially alike. The posterior ligament was cut by introducing a knife blade behind, as is done in tenotomy, cutting backward until there was left only the tendon of the triceps, without its fibres running laterally to the condyles.

Experiment, November 14, 1893. Division of the following structures, successively: Internal condyle, lateral

ligament, anterior ligament, external condyle, external lateral ligament, posterior ligament. The tendon of the triceps only is left.

Arm from dissecting room. Muscles intact. Internal condyle chiselled. The fracture enters trochlea near its inner border. The fragment is best held in the acute position. Lateral ligament on that side divided. Now the fragment is very movable in the extended position, and also in the right-angled position, but in the acute position it is held apparently by the tenseness of the fibres running from the internal epicondyle. Just as soon as the ulna gets a little inside the right angle (at about 80°), the internal condyle commences to turn up into its place and become fixed.

Then the anterior ligament is cut, which leaves the condyle very free. In the extended position the fragment falls forward and outward, and will not remain in place. In the acute position it is brought up quite well into place, and is held pretty firmly.

The external condyle is now cut through, the line of fracture running across the joint, into the first fracture, making a T-fracture. In the extended position everything is loose, and nothing is held in position, while in acute flexion things are held better than in any other way. With so much tissue lost it is, of course, impossible for the fragments to be kept exactly in place, and in other than the acute position there is no attempt at it apparently.

The posterior ligament is now divided, and there remains only the tendon of the triceps. In the extended position the front of the joint is absolutely open, the fragments rolling in every direction, and showing no tendency to keep in place, even after having been put together. As the forearm is flexed and gradually brought to an acute angle with the upper arm the separated condyles, without further manipulation, come very nearly into place. After being pressed into position with the hand they are held there very firmly. This is a very striking performance, and is repeated over and over again, but uniformly with the same result.

Any conclusions drawn from the preceding experiments must be made with certain reservations, due

chiefly to the difference in the conditions as met with in the cadaver and the recently injured arm. It is quite impossible to say, for instance, that the fracture caused by a chisel, where there is generally no comminution, where the line of fracture is comparatively a straight one, and where there is usually little or no rupture of ligaments or stripping up of the periosteum, will behave like a recent fracture in the living arm, where all these conditions may easily be quite the opposite, and where, moreover, there is synovial effusion, extravasation of blood, and spasm of torn and irritated muscles.

Such or similar limitations, however, are common to all purely experimental work, and if given proper weight, do not prevent us from making valuable deductions.

The following conclusions seem to be justified:

(1) When either condyle of the humerus is broken off into the joint, the fragment remains closely attached to the bone below, whose motions it follows.

(2) The fragment of a fractured condyle can be most surely replaced in its normal position by the following manœuvre: forcible extension followed by pressure on upper end of ulna, downward and backward, while the forearm is being pronated and flexed to an acute angle with the upper arm.

(3) The same manœuvre acts equally well in replacing the fragments if the fracture be of both condyles, a transverse fracture of the lower end of the humerus (probably it would be true also of the epiphyseal separation), or a T-fracture.

(4) In all these fractures involving the joint the fragments are held most firmly in place, that is, are least susceptible to displacement from forces acting from without, if the elbow is tightly flexed. The next best position, in this regard, is the position of

forced extension (not loose extension), while the greatest mobility is met with in the position of 100° of flexion.

(5) Forced extension in all cases causes a rotation of the fragment forward. A less degree of extension, which will not do this, allows the fragment great freedom of motion.

(6) The essential factors in the locking of the fragments in the acute position, seem to be the coronoid process in front and the ligamentous and muscular structures behind. The tendon of the triceps is sufficient if the posterior ligament is divided, and the ligament is sufficient if the muscle is removed.

However pleasing these experiments may be in the simplicity and definiteness of their results, it is natural that some question should arise as to their application in practice. The treatment of elbow injuries by flexion to a point slightly less than a right angle is not new. But the present scheme contemplates a flexion which shall purposely make tense the structures behind the articulation, a position which it would seem, might easily be carried so far as to endanger the tissues in front of the joint and cut off the blood-supply of the forearm. Again, it might be thought that such a position would be exceedingly painful, or at least irksome, to the patient.

In the cases thus far observed, however, no unpleasant symptoms have been met with. In but one case was it necessary to change the angle, and that was for a single day only. Pain, or even discomfort, has not been complained of, nor has there been any kind of disturbance in the circulation of the forearm.

If the conditions of the experimental fracture are realized in actual practice, and the fragments are held in almost exact position, and kept there absolutely with-

out motion, then it may reasonably be expected, from the general principles governing the repair of bones, that there will be a minimum of exudate, a minimum of callus-building, union practically by first intention, the least possible thickening of ligaments and formation of adhesions, and the smallest amount of extra bone-formation; or, in other words, the quickest possible repair, with the least impairment of function.

Next in importance to the preservation of the mobility of the joint is the desirability of maintaining the normal angle between the humerus and ulna. The exact value of this angle, in a practical way, may be a question worthy of separate consideration. It is certainly true that not a few surgeons deem it of sufficient importance to serve as a basis for a special method of treatment, preferring apparently, to run the risk of anchylosis with the forearm extended, than to run the chance of an unnatural inward angle.

Any position which restores the parts exactly to their proper places cannot fail to preserve the normal angularity. Aside from this assumption, however, there is reason to believe, on theoretical grounds, that as long as the ulna is closely flexed on the humerus it is impossible for such a displacement of the fragments to occur as to reverse the usual humero-ulnar angle. It is generally stated that this angle is due to the obliquity of the axis of the joint to the axis of the humerus. As a matter of fact, it is due in a larger degree to the obliquity of the axis of the ulna to the axis of the joint.[8]

[3] Strangely enough this fact seems to have escaped the attention of anatomists and surgeons. The writer has made careful measurements in a large number of bones and of freshly dissected arms, the results of which it is proposed to collate and publish later. It is the more curious that attention has not been directed to this point because a great deal of study has been devoted to the curious mechanism and motions of the joint, and this simple relation of the shaft of the ulna to its articular axis, really furnishes a key to the mechanism, rendering much more simple a matter which otherwise seems very obscure.

If the humero-ulnar angle (the so-called "carrying angle") were due, as is usually stated, to the obliquity of the axis of the joint to the axis of the humerus, then in flexion of the forearm the latter would be carried to the inner side of the arm, as in the diagram. (Fig. 2.) But this is not the case. The obliquity existing in both bones, though not usually to an equal degree, the forearm when acutely flexed, lies nearly

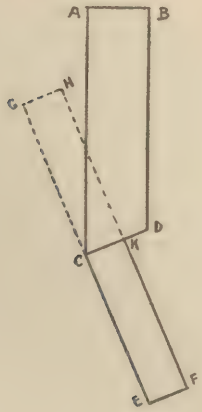

FIG. II.

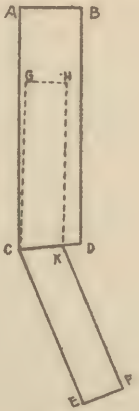

FIG. III.

in the plane (antero-posterior) of the arm. (Fig. 3.) No matter, then, what the fracture may be, if, the forearm being acutely flexed, the humerus and ulna are kept in this same plane during treatment, when the forearm is extended, the ulna will be carried outward, reproducing very closely, at least, the normal angle.

As long as the lateral ligaments are untorn, it is not possible for either condyle to be so displaced upward

as to change the direction of the axis of motion in the joint to such an extent as to overcome this natural inclination of the ulna outward. In the case of a transverse fracture across the lower end of the humerus, or of a T-fracture, it is perhaps possible for this to occur, but even then it would be unlikely unless the forearm bones were flexed to less than an acute angle, that is, to a point somewhere between 90° and 60°.

At the time the foregoing paper was read in January, 1894, there were reported ten cases in which elbow injuries of various kinds had been treated by acute flexion. The results obtained in these cases were so satisfactory, that since that time the majority of injuries of this class occurring at the City Hospital have been so treated, and the writer is not aware of any case in which the result has been other than satisfactory. As it is intended to collect and study all these cases more carefully in the future, they will not be printed here. Since some of them, however, were carefully manipulated under ether, with a view to test the correctness of the results obtained in the experimental fractures, the following notes, made at the time of the examination, and confirmed in each case by other observers, are subjoined.

Case. Fracture of internal condyle.

C. O'L., a large boy of sixteen, fell on the ice December 27, 1893, striking on the left elbow. A temporary dressing was applied at the New England Hospital, and he came to the City Hospital on the morning of the 28th. Under ether there was found to be a fracture of the internal condyle running well into the joint. There was slight swelling, and the detection and study of the fracture was exceptionally satisfactory. Crepitus was best obtained by alternately flexing and extending the forearm, at the same time mak-

ing downward pressure upon the internal epicondyle. The humero-ulnar angle of the right arm was estimated to be eight degrees. By adduction of the forearm that of the left elbow could be reduced to nothing, while by abduction it could be increased to ten degrees or more. When adduction was made, the fragment was carried forward and upward. Reduction was accomplished in the manner heretofore described, and tracings taken before and after the manipulation showed conclusively that the position was improved. The forearm was held at 45° of flexion by adhesive plaster.

When the forearm was extended, the fragment could be felt to bulge forward beneath the skin, and it was noted that in this position, as well as when the elbow was at right angles, the fragment could be easily displaced.

Case. Separation of epiphysis. Acute flexion. Slight internal angle.

M. D., a girl of twenty months, November 12, 1893, fell down a flight of stairs. She entered the service of Dr. M. F. Gavin, by whose kindness I am allowed to report the case. I saw her four hours after the injury, at which time there was great swelling of the left elbow region, with commencing ecchymosis on the outer aspect of the joint. Careful examination under ether disclosed a transverse fracture of the lower end of the humerus, the line of fracture seeming to be at the epiphyseal junction on the outer side, while on the inner side it ran higher up through the bony structure above the internal epicondyle. At first the forearm could be flexed only to a right angle, but after some manipulation full flexion was possible. On extending the forearm it was found to be adducted in relation to the humerus, the two forming an inwardly open angle of about ten degrees. It was easy to increase the amount of adduction and with it, of course, this inward angle. In the normal arm the humero-ulnar angle was nothing, the arm and the forearm being in the same straight line. After going through the motion of reduction in the manner already explained, and then carefully extending the forearm, without disturbing the fragment, the inward angle was found to have disappeared, the arm and forearm being in one straight line.

By experimenting it was found that if the arm was fully

extended, the fragment was easily moved out of position and tended to project forward. In the right-angled position the same thing was true, while in the acute position the fragment seemed locked, and in very fair position, although the internal epicondyle did not seem to be as prominent as upon the other side. By no amount of manipulation, however, and in no position could the epicondyle be made any more prominent.

The forearm was put up at about 60° with adhesive plaster. The radial artery could be felt to pulsate, and there was no lividity of the fingers. Tracings were taken before and after the reduction, and it was evident that the position had been improved.

December 7th, about four weeks after the injury, the strapping was omitted, and the arm left free, there having been no trouble whatever from pain or pressure in the mean time. December 28th, six and a half weeks after injury, flexion, rotation and extension were absolutely perfect. There was a very slight internal angle at the elbow (three to five degrees). The bony prominences were practically in their normal relative positions, and the child could use the arm almost perfectly.

This appears to have offered one of the severest tests possible. The writer is very firmly convinced from a series of studies which he hopes to publish later, that it is in exactly this class of fractures, namely, separation of the epiphysis, that the peculiar gun-stock deformity is most often met with. In the above case the deformity is trifling, and the return of function all that could be wished.